

Original Article

Trampoline performance under changing visual conditions

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ABSTRACT

Picking up and utilizing visual information is thought to be of high importance in the control of trampoline skills. Yet, the question arises how information from the different vision systems contributes to trampoline gymnastics performance. The aim of this study was to examine the role of binocular and monocular visual information in trampoline gymnastics. $N = 12$ gymnasts performed straight leaps on the trampoline under full vision, monocular vision, and under occluded vision. Gymnasts' preferred flight duration as well as gymnasts' variable error in feet placement on the trampoline bed were analysed by means of an optic movement analysis system. Results revealed that gymnasts exhibited longer flight duration in the binocular vision condition and the monocular vision condition, as compared to the occluded vision condition. Gymnasts furthermore exhibited a larger variable error in feet placement with less visual information available. It is argued that gymnasts benefit from the availability of binocular information in order to perform precise leaps on the trampoline. Nevertheless, utilizing visual cues in trampoline gymnastics seems to depend on the current configuration of task-constraints (i.e., performing straight leaps vs. somersaults with and without twists). **Keywords:** Monocular vision; Binocular vision; Occluded vision; Flight duration; Variable error.

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INTRODUCTION

Trampoline gymnastics affords a precise interaction of the gymnast with the trampoline bed in order to perform the intended skills (Kelly, 2014). Picking up and utilizing visual information is thought to be of high importance in the control of trampoline skills (Raab, de Oliveira, and Heinen, 2009). Nevertheless, the question arises how information from the different vision systems contributes to trampoline gymnastics performance. The aim of this study was to examine the role of binocular and monocular visual information in trampoline gymnastics.

When a gymnast performs on the trampoline, he/she picks up information from the different perceptual systems (i.e., visual, auditory, etc.; Magill, 2011; Vickers, 2007). This information is integrated and utilized to regulate action in order to achieve the current movement goal (Latash, 1993; Warren, 2006). In particular, information picked up from the visual system is thought to be an important component in the aforementioned process. It enables the performer to pick up distal information from the environment that can be used in an anticipatory manner when regulating one's own movements with regard to the environment (Bardy and Laurent, 1998; Caljouw, van der Kamp, and Savelsbergh, 2004).

Several authors (Davlin, Sands, and Shultz, 2001a, 2001b; Hondzinski and Darling, 2001; Luis and Tremblay, 2008; Rézette and Amblard, 1985) questioned for instance the role of different visual cues in the performance of complex gymnastics skills. In these studies, usually skilled athletes were asked to perform gymnastics skills such as forward somersaults (Bardy and Laurent, 1998; Lee, Young, and Rewt, 1992), standing backward somersaults (Davlin et al., 2001a, 2001b; Luis and Tremblay, 2008), double backward somersaults (Hondzinski and Darling, 2001), or even backward somersaults with twist (Rézette and Amblard, 1985) in different experimental conditions.

In one study, ten female gymnasts were asked to perform standing back tuck somersaults from a foam block in four conditions (Davlin et al., 2001a): full vision, vision restricted to the first half of the somersault, vision restricted to the second half of the somersault, and no vision. Gymnasts' movement kinematics (i.e., time structure) as well as landing balance were assessed. In particular, results revealed that gymnasts performed more stable landings when vision was available the whole time or during the second half of the somersault (i.e., when gymnasts could direct their gaze towards the landing area). Experimental conditions in similar studies usually comprised the manipulation of further visual cues, such as continuity of visual information (Rézette and Amblard, 1985; Luis and Tremblay, 2008), peripheral vision (Davlin et al., 2001b), or foveal vision (Hondzinski and Darling, 2001). Results of the aforementioned studies generally revealed better landing performance under conditions where vision was available, and worse landing performance under no-vision conditions. This in turn clearly supports the importance of visual information when performing complex skills in which anticipation of landing is directly related to skill performance. It can thus be concluded that visually perceiving the landing mat (and thus anticipating the landing impact) is important for landing stability.

Visual perception (of a three-dimensional environment) comprises monocular cues, binocular cues, and oculomotor cues (Eysenck and Keane, 2015). Researchers have studied the role of binocular vision and monocular vision in the performance of different (more complex) motor tasks ranging from postural control (Isotalo, Kapoula, Feret et al., 2004), over locomotion (Hayhoe, Gillam, Chajka, and Vecellio, 2009; Patla, Niechwiej, Racco, and Goodale, 2002) to ball-catching (Mazyn, Lenoir, Montagne, and Savelsbergh, 2004; Olivier, Weeks, Lyons, Ricker, and Elliott, 1998), and golf-putting (Bulson, Ciuffreda, and Ludlam, 2009).

In one study, 18 participants with either normal or weak stereopsis were asked to catch tennis balls in upright stance (Mazyn et al., 2004). Tennis balls were projected by a ball machine at differing velocities, and participants were allowed either to use binocular vision, or monocular vision with the preferred eye covered with an eye patch. Results revealed that catching performance was better under lower ball velocities. Furthermore, participants with normal stereopsis usually performed worse in the monocular viewing condition as compared to the binocular viewing condition. In addition, participants with weak stereopsis exhibited no difference in catching performance between viewing conditions (although their catching performance under binocular viewing conditions was worse under high ball velocities compared to participants with normal stereopsis). This finding was in line with results of other studies questioning the role of binocular and monocular vision in motor control (see above). These studies usually revealed better motor performance under binocular versus monocular viewing conditions, in particular when participants' task comprised an anticipation component with a defined degree of spatial precision (i.e., precisely catching a ball, or stepping over an obstacle; Gray and Regan, 2004). It can thus be concluded that visual perception results from integrating different cues, while precision in motor control may be facilitated with more specific and task-relevant information available.

Taken together, it can be stated that picked-up visual information is of high importance when performing complex (gymnastics) skills. However, it is still questionable how information from the different vision systems (i.e., binocular vs. monocular) contributes to trampoline gymnastics performance. Empirical evidence from research addressing the role of binocular and monocular vision in other (whole-body) tasks supports the notion that motor control is more precise when binocular information is available. In particular, performance in tasks with an anticipation component may benefit from binocular information. Thus, one could speculate that binocular vision first and foremost supports landing precision when performing leaps on a trampoline. The aim of this study was therefore to examine the role of binocular and monocular visual information in gymnasts performing straight leaps on the trampoline. It was assumed that gymnasts would exhibit a higher precision (i.e., smaller variable error) in feet placement under full vision compared to monocular vision or occluded vision. Gymnasts' preferred flight duration should, however, not be influenced under monocular vision, but could be influenced when no vision is available (Gray and Regan, 1998).

MATERIAL AND METHODS

Participants

$N = 12$ trampoline gymnasts ($M_{age} = 17$, $SD = 3$ years) participated in this study. The gymnasts had an average training experience of seven years. They practiced in average six hours per week, and they reported to participate in regional and national trampoline championships. Gymnasts' task was to perform straight leaps on a competition trampoline while visual information was systematically manipulated (see Instruments and Procedure). The gymnasts were informed about the procedure of the study and they gave their informed written consent prior to the beginning of the study. The study was carried out in line with the guidelines of the local university's ethical committee.

Measures

Motor Task

The motor task was to perform straight leaps on a competition trampoline (size of trampoline: 520 x 305 cm, size of jumping bed: 426 x 213 cm) in two experimental conditions, and in a baseline condition. A straight leap consists of a *contact phase*, and a *flight phase*. During the contact phase, gymnasts' feet are in contact with the jumping bed. The aim of the contact phase is to prepare the flight phase (i.e., generate linear momentum). The take-off velocity determines the trajectory of the flight phase, and thus the duration of the

flight phase (Hay, 1993; Horne, 1978). The duration of the flight phase as well as the position of gymnasts' feet on the trampoline bed during the contact phase were assessed. The trampoline was arranged according to the competition rules of the International Gymnastics Federation (FIG, 2017). Elevated safety mats were placed behind and in front of the trampoline. Additional safety mats were placed on both long sides of the trampoline.

Movement Analysis

An optic movement analysis system with a sampling rate of 240 Hz was used to determine motor performance on the basis of video sequences of all leaps. One digital video camera was attached to the ceiling of the gymnasium (top camera, approximate height of 20 meters; the optical axis was aligned at an angle of approximately -20° from the vertical towards the middle of the trampoline bed) in order to videotape the spatial position of gymnasts' feet on the trampoline bed during the contact phase of the straight leaps. An additional digital video camera was placed above the stands and about 15 meters away from the trampoline in order to videotape gymnasts' feet during the contact phase (front camera; optical axis aligned at an angle of -10° from horizontal towards the middle of the jumping bed).

First, the horizontal coordinates of both tiptoes were recorded and averaged for each touchdown point of each of ten successive leaps (see Procedure) videotaped by the top camera using the movement analysis software WINalyze 3D (Mikromak, 2008). The jumping bed of the trampoline was used as calibration scale. From the coordinates of the touchdown positions, the variable errors in both horizontal directions were calculated for each gymnast in each condition as an indicator of consistency of feet placement during the straight leaps (Magill, 2011).

Second, the time of each take-off point and each touchdown point for each of ten successive straight leaps were recorded from the front camera. The take-off point was defined as the video frame with the last visible contact of gymnasts' feet with the trampoline bed. The touchdown point was defined as the video frame with the first visible contact of the gymnasts' feet with the trampoline bed. From the difference of both values, the duration of the flight phase was calculated. The values for flight duration were averaged for each gymnast in each condition.

Procedures

The study was conducted in three phases. In the first phase, the participating gymnast arrived at the gymnasium and signed the informed consent form. The gymnast was given a 15-minute warm-up phase to ensure that he/she was physically prepared. In the second phase, the gymnast was asked to perform two blocks of ten leaps in direct succession in each of the two experimental conditions, and in the baseline condition. During the first block of ten leaps the gymnast was asked to reach his/her preferred time of flight during the straight leaps. During the following block of ten straight leaps, the gymnast was asked to try to hold the time of flight as constant as possible. Gymnasts' performance during the second block of ten leaps was used for later data analysis.

In the baseline condition (*full vision*), the gymnast was allowed full vision with both eyes open. In the first experimental condition (*monocular vision*), the gymnast was allowed monocular vision only. Therefore, gymnasts' dominant eye was occluded by an eye-patch (Coull, Weir, Tremblay, Weeks, and Elliott, 2000). In the second experimental condition (*occluded vision*), the gymnast was asked to wear goggles occluding visual information (Davlin et al., 2001a; Luis and Tremblay, 2008). The two experimental conditions (*monocular vision*, *occluded vision*), and the baseline condition (*full vision*) were presented in a randomized order for each gymnast. There was no time pressure in this study and the participating gymnast was allowed

to take breaks as requested. In the third phase of the experiment the participating gymnast was debriefed and dismissed.

Analysis

A significance criterion of $\alpha = 5\%$ was defined a-priori for all statistical analyses. Separate t -tests for paired samples were calculated to analyse differences in the dependent variables between the different study conditions. Flight duration as well as variable error of feet placement on the trampoline bed in both horizontal directions during the contact phase of the straight leaps were used as dependent variables. Cohen's d was calculated as an effect size for significant effects.

RESULTS

It was assumed that gymnasts would exhibit a smaller variable error in feet placement under full vision compared to monocular vision or occluded vision. Gymnasts' preferred flight duration should, however, not be influenced under monocular vision, but could be influenced when no vision is available. To test these assumptions, flight duration of the straight leaps as well as variable error of feet placement on the trampoline bed in both horizontal directions during the contact phase of the straight leaps were analysed between study conditions.

First, results revealed significant differences in flight duration between the study conditions. Gymnasts exhibited longer flight duration in the full vision condition as compared to the occluded vision condition ($t_{11} = 4.706$, $p < .01$, Cohen's $d = 1.235$). In addition, flight duration was in average longer in the monocular vision condition as compared to the occluded vision condition ($t_{11} = 4.283$, $p < .01$, Cohen's $d = 1.121$, see Figure 1). Gymnasts exhibited a 0.087 seconds' shorter flight duration under occluded vision compared to monocular vision, and a 0.100 seconds' shorter flight duration under occluded vision compared to full vision.

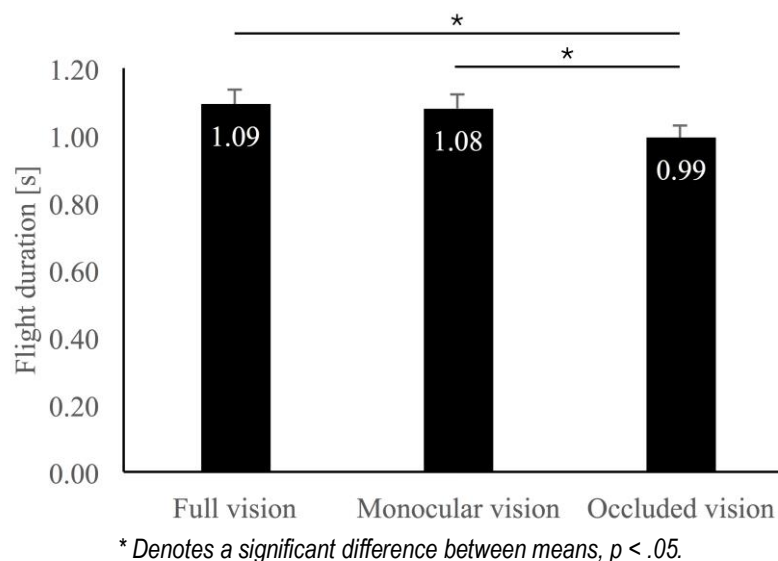
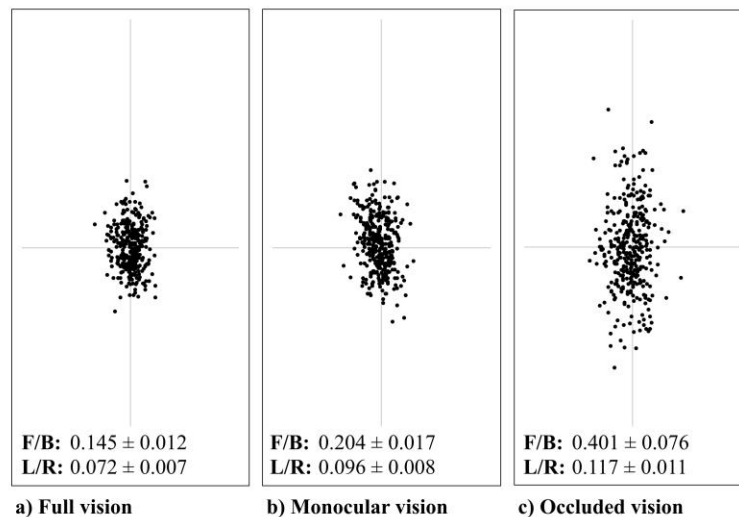


Figure 1. Average flight duration (mean \pm standard error) of the straight leaps in the three study conditions.

Second, results revealed significant differences in variable error of feet placement on the trampoline bed between the study conditions. Gymnasts exhibited a smaller variable error in feet placement in both horizontal directions in the full vision condition compared to the monocular vision condition ($t_{11} = 3.617$.. 4.435, $p < .01$,

Cohen's $d = 0.924 \dots 1.177$), as well as compared to the occluded vision condition ($t_{11} = 3.902 \dots 4.832$, $p < .01$, Cohen's $d = 1.012 \dots 1.278$). In addition, variable error in feet placement in both horizontal directions was smaller in the monocular vision condition compared to the occluded vision condition ($t_{11} = 2.295 \dots 2.977$, $p < .01$, Cohen's $d = 0.556 \dots 0.745$, see Figure 2). In average, variable error of feet placement under monocular vision was 1.36 times as large as variable error of feet placement under full vision. Variable error under occluded vision was 2.20 times as large as variable error under full vision.



(F/B = forward-backward direction, L/R = left-right direction, values are presented as means \pm standard errors).

Figure 2. Distribution of feet placement on the trampoline bed as well as variable error in both horizontal directions during the contact phase of all analysed straight leaps in the three study conditions.

Taken together, gymnasts exhibited a slightly shorter flight duration when no vision was available (occluded vision condition) as compared to when visual information was available (full vision condition and monocular vision condition). Furthermore, gymnasts exhibited a larger variable error in feet placement with less visual information available (i.e., occluded and monocular vision compared to full vision).

DISCUSSION & CONCLUSIONS

The aim of this study was to examine the role of binocular and monocular visual information in trampoline gymnastics. To approach this aim, gymnasts performed straight leaps on the trampoline under full vision, monocular vision, and occluded vision. Results revealed that gymnasts exhibited longer flight duration in the full vision condition and the monocular vision condition, as compared to the occluded vision condition. Furthermore, gymnasts exhibited a larger variable error in feet placement with less visual information available.

It is argued that information picked up from the visual system is of high importance even in the performance of rather simple skills such as leaps on the trampoline. This becomes immediately obvious when comparing gymnasts' performance in the condition where no vision was available to the conditions where vision was available. Gymnasts contacted the trampoline bed with a higher precision when they could access visual information. Only relying on information from other perceptual systems (i.e., vestibular information or somatosensory information) may lead to a worse perception of body position and orientation during the contact phase of the straight leaps. This in turn could go along with a more variable contact phase and a

larger deviation when leaving the trampoline bed for the flight phase of the straight leaps. Information from the vestibular system comprises for instance linear and rotation acceleration, and inferring body orientation from vestibular information alone is usually hampered compared to when visual information and vestibular information are available (Latash, 1993). Nevertheless, the fact that the experienced gymnasts in this study were able to perform straight leaps under occluded vision, additionally highlights the important role of information picked up from the other perceptual systems. Experienced gymnasts are not only able to perform under occluded vision but they are obviously able to partly compensate the missing visual information with information from the remaining perceptual systems.

However, when full visual information was available, the gymnasts exhibited a smaller variable error in feet placement compared to when only monocular information was available, thus highlighting that not only monocular cues (i.e., monocular time to contact information; Gray and Regan, 1998) but binocular cues (i.e., stereopsis, binocular time to contact information; Gray and Regan, 2004) are important in performing precise leaps on the trampoline. In particular, when performing subsequent leaps, the gymnast has to anticipate his/her contact with the trampoline bed from leap to leap and thus compensate for deviations on the trampoline bed from leap to leap. This compensation could be facilitated by utilizing binocular visual information. Evidence from studies comparing people with weak stereopsis to normal controls usually highlights that people with weak stereopsis exhibit no difference in task performance under binocular and monocular viewing conditions (Mazyn et al., 2004). Nevertheless, participants with weak stereopsis exhibit worse performance under tightened task-constraints (i.e., higher ball velocity when trying to catch balls) compared to participants with normal stereopsis. Thus, one could speculate that the utilization of monocular and binocular cues in performing leaps on the trampoline could depend on the current configuration of task-constraints, and therefore differ between viewing situations that occur when gymnasts not only perform straight leaps but more complex skills incorporating rotations about the twist and/or somersault axis.

Gymnasts exhibited a slightly reduced flight duration under occluded vision as compared to when vision was available. Given that gymnasts were instructed to perform the straight leaps with their preferred flight duration, it may either be the case that gymnasts overestimated flight duration under occluded vision, or became influenced by some degree of precariousness when performing blindfolded. However, the gymnasts in this study could be characterized as 'experienced', and none of them reported having felt precarious or insecure when performing leaps with occluded vision. Nevertheless, when vision is occluded, there is no optic flow information (and therefore no visual time-to-contact information) available (i.e., Lee et al., 1992). Thus, it can be speculated that even experienced gymnasts rely on visual time-to-contact information in rather simple skills, such as straight leaps, and that flight duration is overestimated (i.e., shorter flight duration) when no time-to-contact information is available (Gray and Regan, 1998). Furthermore, it cannot be ruled out that there may be a (subtle) effect of uncertainty on gymnasts' arousal and motor control, in particular when performing with occluded vision (Enoka, 2002).

There are several limitations of this study and two particular aspects should be highlighted. First, experienced gymnasts were asked to perform straight leaps on the trampoline in different vision conditions. Given that gymnasts exhibited a larger variable error in feet placement under monocular vision, one could speculate whether performing skills under monocular vision could be a suitable perceptual training condition in order to increase gymnasts' sensitivity for different visual cues in the performance of (complex) trampoline skills (Savelsbergh and Whiting, 1992). In addition, the question arises how the role of binocular vision and monocular vision changes during skill acquisition processes, and/or differentiates between gymnasts of different expertise levels. These questions could be addressed in subsequent studies. Second, gymnasts pick up information from the different perceptual systems when performing skills on the trampoline. While

visual information maybe the most trusted information, the question yet arises how information from other perceptual systems (i.e., auditory information) interacts in synchronized trampoline gymnastics, where the task is not only to perform intended skills but to coordinate skill performance to that of a partner (Heinen, Koschnick, Schmidt-Maaß, and Vinken, 2014). Thus, a subsequent study could address the role of information from other perceptual systems in the emergence of coordinated behaviour in synchronized trampoline gymnastics.

There are some practical implications and one particular aspect should be highlighted. It is argued that gymnasts should strive to maintain visual contact with the apparatus or the environment while performing on the trampoline (Sands, 1991). This may help the gymnast anticipating touchdown on the trampoline bed for subsequent leaps and landings. It furthermore supports leap-to-leap precision in feet placement when performing a sequence of skills. The current Code of Points in trampoline gymnastics affords a precise placement of the feet from leap to leap (FIG, 2017). Therefore, the utilization of perceptual information in order to minimize deviation in feet placement from the middle of the trampoline bed may yet be an important aspect to be emphasized in daily training.

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CONFLICT OF INTEREST

The authors of this study report no conflict of interest.

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